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Art. XII.—*On a Limestone containing Lepidocyclina and other Foraminifera from the Cape Range, Exmouth Gulf, W.A.*

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(With Plate XII.)

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Contents.

I. Introductory Remarks.

Although various species of the genus *Lepidocyclina* are well-known components of Australian Tertiary limestones, there have hitherto been no records of *Lepidocyclina dilatata* Michelotti, a species which belongs to the group having a tangential embryonic megasphere. It was, therefore, extremely interesting to receive from Mr. W. S. Dun, of the Department of Mines, Sydney, several specimens of limestone containing these and other foraminifera which had been collected from cliffs of whitish or cream-coloured limestone from the Tertiary rocks of the "Cape Range," south from North West Cape, 25 miles N.W. of Exmouth Gulf Station Homestead, in a deep gorge.

Dr. F. G. Clapp, who collected the specimens, has already published a valuable and extremely interesting paper entitled "A Few Observations on the Geology and Geography of North-West and Desert Basins, Western Australia" (Clapp, 1925). His remarks on this particular limestone deposit may here be quoted with advantage (loc. cit., pp. 64, 65):

"*The 'Cape Range' Formation.*

"The most unexpected discovery of any relation to the Tertiary system was in the 'Cape Range,' extending south from North-West Cape, where white limestones and interstratified chalky beds form a great anticline rising from below sea-level on the west side of Exmouth Gulf to a height of over 1000 feet in the centre of the Range . . . . intersected by deep gorges extending back miles into it. Some beds of the chalky material are full

of foraminifera, as yet unidentified, and only surmised to be of Tertiary age."

Then follows a footnote dated 29th March, 1925;—"Word has just been received from Professor Sir T. W. E. David that Mr. F. Chapman states emphatically that these foraminifera are Oligocene types of *Lepidocyclina* and *Cycloclypeus*. The above is therefore an important discovery of raised and flexed Oligocene limestones in Western Australia.—Ed."

Dr. Clapp continues his description as follows:—

"The east dips vary from nil on top of the Range to 8 degrees on the lower east flank. Far up a gorge in the range, at a point 15 miles south of North-West Cape, I saw the dip flatten out and then dip toward the west at an angle of 2 degrees; but the Gorge was not followed farther west. Rocks are also reported to dip seawards at Pt. Cloates, 75 miles south of North-West Cape, on the west side of the Range." Dr. Clapp adds: "East of the anticline of Cape Range other anticlines were found, one of which, on Giralia Station, 20 miles east of Cape Range, has a height of at least 300 feet and a breadth of 10 miles."

From the above notes by Dr. Clapp it will be seen that the Oligocene formation is quite extensively developed on the West Coast of Australia, the discovery of which came too late to incorporate in the text of the paper on "The Tertiary Deposits of Australia" by F. A. Singleton and myself, published in the *Proceedings of the Pan-Pacific Science Congress*, Australia, 1923, where we remark (p. 991): "In the absence of palaeontological evidence, however, it is not always possible to make a distinction between Tertiary strata and the formation known as the Coastal Limestone, consisting of consolidated sand-dunes of Post-Tertiary age, which is extensively developed along the western and south-western coasts of Western Australia." The approximate location of the present occurrence was, however, inserted in the accompanying map, facing p. 991.

II. Description of the Rock.

This limestone is, in most samples submitted, moderately friable, but in others too hard to be disintegrated by immersion or crushing in water. It breaks with a ragged surface. The colour varies from a pale cream to yellowish, or sometimes pink, on the older weathered surfaces. The larger foraminifera are conspicuous throughout the rock, and are exposed by fracture of the surface.

An examination of the finer constituents of the limestone shows coccoliths to be fairly abundant; they measure 16 μ in diameter. There is a small dark nuclear spot in the middle of the disc, a wide, clear or radiately striate zone and a thin outer ring. Rhabdoliths are also numerous, appearing as rod-like bodies, either fusiform or with swollen ends; they measure circ. 39 μ. Flakes of shelly material are abundant, also rhomb crystals of secondary calcite or perhaps dolomite, circ. 20 μ in diameter.

Fragments of echinoid tests and spines are recognisable in these washings.

The finer washings also contain many minute foraminiferal tests, which have otherwise escaped corrosion.

The medium or coarser washings show abundant foraminiferal remains, but many, especially those belonging to the more coarsely perforated genera, as *Gypsina* and *Lepidocyclina,* have been corroded. This partial solution of the organisms has given rise to the secondary calcite crystals so freely scattered through the mud or finer portions of the limestone.

The larger foraminifera, as *Lepidocyclina* and *Cycloclypeus,* appear to occur in certain bands, especially in the finer, cream-coloured limestone; whilst the yellowish limestone is more prolific in the smaller kinds of foraminifera, as *Anomalina, Truncatulina* and *Discorbina.*

III. Conditions of Deposition.

The assemblage of foraminifera met with in this limestone or marly limestone of Exmouth Gulf, indicates a sub-tropical to tropical phase of deposition and comparable to that of a moderately deep water coral sand formation.

The conspicuous element in this fauna consists of abundant tests of the discoidal kinds of foraminifera, and this indicates shallow to moderately deep water. This type of foraminiferal deposit is comparable to that prevailing round coral islands at the present day, as, for example, at Funafuti, in the South Pacific, where *Cycloclypeus* was similarly abundant at about 50 to 200 fathoms.

The smaller foraminifera here present include numerous *Miliolinae,* the minute arenaceous forms such as *Spiroplecta, Bolivina* and *Cassidulina,* and the lagenids, as *Nodosaria* and *Cristellaria,* which are usual concomitants of clear water at fair depths. The open water character of the deposit is also indicated by the presence of the pelagic forms, as *Globigerina.*

IV. Systematic List and Description of the Fauna.[1]

Phylum **PROTOZOA.**

Class RHIZOPODA.

Order FORAMINIFERA.

Fam. MILIOLIDAE.

Sub-fam. MILIOLININAE.

Genus **Biloculina** d'Orbigny.

BILOCULINA BULLOIDES d'Orbigny.

Biloculina bulloides d'Orbigny, 1826, p. 297, pl. xvi., f. 1-4. Schlumberger, 1887, p. 120, pl. xv., f. 10-13. Chapman, 1907, p. 13, pl. i., f. 3, 4.

1.—My best thanks are due to Mr. W. J. Parr for much painstaking work in selecting a large part of the smaller foraminifera herein recorded.

Observations.—This well-known recent species has a geological range in Australia extending down to the Oligocene (Muddy Creek and Port Phillip). The tests vary in outline from slightly elongate or sub-oval to sub-circular.

Occurrence.—Frequent; small.

Genus **Miliolina** Williamson.

Miliolina oblonga (Montagu).

Vermiculum oblongum Montagu, 1803, p. 522, pl. xiv., f. 9.
Triloculina oblonga (Mont.), Cushman, 1917, p. 69, pl. xxvi., f. 3.

Observations.—This species has a long geological range. It is found in various Tertiary deposits in Victoria, notably at Muddy Creek and Port Phillip (Balcombian). It is also a well-known recent species.

Occurrence.—Frequent; rather small.

Miliolina pygmaea (Reuss).

Quinqueloculina pygmaea Reuss, 1850, p. 384, pl. i., f. 3*a,b*.
Miliolina pygmaea (Reuss), Brady, 1884, p. 163, pl. cxiii., f. 16*a,b*.
Miliolina oblonga Chapman (*non Serpula oblonga,* Mont.), 1907, p. 17, pl. ii., f. 26.

Observations.—This is a minute species of the *M. seminulum* type, but with more numerous chambers. It is trigonal in cross section. As a recent form it inhabits deeper water than other miliolines, as was remarked by Dr. H. B. Brady. It has occurred as a fossil in the Miocene of the Vienna Basin and in the Oligocene of Port Phillip, Victoria.

Occurrence.—Very rare.

Miliolina seminulum (Linné).

Serpula seminulum Linné, 1767, No. 791. Id., 1788, p. 3739, No. 2.
Miliolina seminulum (L.), Brady, 1884, p. 157, pl. v., f. 6*a-c*. Chapman, 1907, p. 19, pl. ii., f. 34.

Observations.—A common, fairly shallow water form. It occurs abundantly in the Victorian Mid-Tertiary series.

Occurrence.—Frequent; small.

Miliolina trigonula (Lamarck).

Miliolites trigonula Lamarck 1804, p. 351, No. 3; 1822, p. 612, No. 3.
Miliolina trigonula (Lamarck), Chapman, 1907, p. 18, pl. ii., f. 30.
Triloculina trigonula (Lam.), Cushman, 1917, p. 65, pl. xxv., f. 3.

Observations.—This species has already been recorded fossil from the Australian Tertiary beds of Port Phillip (Oligocene).

Occurrence.—Rare, typical.

Fam. LITUOLIDAE.

Subfam. LITUOLINAE.

Genus **Reophax** Montfort.

Reophax scorpiurus Montfort.

Reophax scorpiurus Montfort, 1808, p. 330, 83me genre. Cushman, 1910, p. 83, text-figs. 14-16 (p. 84).

Observations.—A commonly distributed species, both fossil and recent.

Occurrence.—Very rare; a stout, obtuse form.

Genus **Haplophragmium** Reuss.

Haplophragmium rotulatum Brady.

Haplophragmium rotulatum Brady, 1884, p. 306, pl. xxxiv., f. 5, 6. Cushman, 1910, p. 104, text-figs. 156, 157.

Observations.—This species was hitherto known only as a recent form. It is interesting to note the present occurrence in beds as far back as the Oligocene.

Occurrence.—Very rare.

Haplophragmium subglobosum (G. O. Sars).

Lituola subglobosa G. O. Sars, 1872, p. 253.

Haplophragmium latidorsatum Brady (*non* Bornemann), 1884, p. 307, pl. xxxiv., f. 7, 8, 10, ?14.

Haplophragmium subglobosum (G. O. Sars), Cushman, 1910, p. 105, text-figs. 162-164 (p. 106).

Observations.—This is a common species, both fossil and recent.

Occurrence.—Very rare.

Fam. TEXTULARIIDAE.

Sub-fam. TEXTULARIINAE.

Genus **Textularia** Defrance.

Textularia gramen d'Orbigny.

Textularia gramen d'Orbigny, 1846, p. 248, pl. xv., f. 4-6. Chapman, 1907, p. 25, pl. iii., f. 53. Cushman, 1911, p. 8, text-figs. 6-8. Chapman, 1926, p. 30, pl. ii., f. 19; pl. v., f. 20*a-c*.

Observations.—The solitary specimen found has the aboral end slightly damaged, but, so far as can be seen, it shows no indi-

cation of a spiroplectine commencement. It is a well distributed form, both recent and fossil.

Occurrence.—Very rare.

Genus **Spiroplecta** Ehrenberg.

Spiroplecta nussdorfensis (d'Orbigny).

Textularia nussdorfensis d'Orbigny, 1846, p. 243, pl. xiv., f. 17-19.

Spiroplecta nussdorfensis (d'Orb.), Chapman, 1907, p. 28, pl. iii., f. 62.

Observations.—This form occurs in the Miocene of the Vienna Basin and the Oligocene of Grice's Creek, Port Phillip. The present example is typical.

Occurrence.—Very rare.

Genus **Verneuilina** d'Orbigny.

Verneuilina triquetra (Münster).

Textularia triquetra Münster, 1838, p. 384, pl. iii., f. 19.

Verneuilina triquetra (Münst.), Brady, 1884, p. 383, pl. xlvii., f. 18-20.

Observations.—In the fossil condition this species occurs both in the Cretaceous and Tertiary. As a living form it inhabits fairly deep water.

Occurrence.—Rare.

Genus **Guembelina** Egger.

Guembelina polystropha (Reuss).

Bulimina polystropha Reuss, 1845-6, p. 109, pl. xxiv., f. 53.

Guembelina polystropha (Reuss), Egger, 1899, p. 34, pl. xiv., f. 31-34, 40. Chapman, 1917, p. 21, pl. ii., f. 19.

Observations.—The example found here is rather more elongate than usual; otherwise it is typical. It occurred in some abundance in the Gingin Chalk of W.A., and it is here evidently a survival of that faunula.

Occurrence.—Very rare.

Sub-fam. BULIMININAE.

Genus **Bulimina** d'Orbigny.

Bulimina elegans d'Orbigny.

Bulimina elegans d'Orbigny, 1826, p. 270, No. 10; Modèles, No. 9. Cushman, 1911, p. 82, text-figs. 134*a-c*.

Observations.—A small but otherwise typical specimen occurs here. It is a Cretaceous and Tertiary fossil species, and was found in Victoria in the Tertiary (Janjukian) beds of the Mallee Bores (Bore 11, 442-444 feet).

Occurrence.—Very rare.

Genus **Bolivina** d'Orbigny.

Bolivina nobilis Hantken.

Bolivina nobilis Hantken, 1875, p. 56, pl. xv., f. 4. Chapman, 1892, p. 516, pl. xv., f. 11. Cushman, 1911, p. 39, text-fig. 64*a,b*.

Observations.—The first appearance of this form seems to be in the Cretaceous. It has been found in the Oligocene of Hungary and in succeeding beds in Europe, and also in the Miocene of the Victorian Mallee Bores. As a recent form it, curiously, is confined to the South Pacific.

Occurrence.—Very rare.

Bolivina spiroplectiformis, sp. nov.

(Plate XII., Fig. 4.)

Description.—Test small, elongate, depressed, with sharp but not carinate margins. The first third of the test is a coiled spiral of about six chambers, including a small central sphere, and this is succeeded by five alternate chambers as in *Bolivina limbata*. The spiral series and the next chamber show re-entrant angulation at place of contact, the angulation directed distally.

Dimensions.—Length. 0·42 mm.; width, 0·173 mm.

Observations.—The resemblance of this form to *B. limbata* is very close, but it differs materially in the coiled commencement. It appears to link up the hyaline bolivine forms with the strictly arenaceous *Spiroplecta*, to a species of which, *S. biformis* (Parker and Jones) (see Brady, 1884, pl. xlv., f. 25-27), it bears some resemblance.

Bolivina punctata d'Orbigny.

Bolivina punctata d'Orbigny, 1839, p. 63, pl. viii., f. 10-12. Chapman, 1907, p. 32, pl. iv., f. 80. Cushman, 1911, p. 32, text-figs. 53*a,b*. Chapman, 1926, p. 40, pl. i. f. 7.

Observations.—A typical specimen was found in the finer washings, which shows the slight curvature at the aboral end, seen in other specimens. It occurs in the Oligocene of Victoria and in the Upper Eocene and Lower Miocene of New Zealand.

Occurrence.—Very rare.

Bolivina textilarioides Reuss.

Bolivina textilarioides Reuss, 1862, p. 81, pl. x., f. 1. Brady, 1884, p. 419, pl. liii., f. 23-25. Chapman, 1907, p. 31, pl. iv., f. 79. Idem, 1926, p. 41, pl. ix., f. 8.

Observations.—This species commences its geological history, so far as recorded, in the Lower Cretaceous. It is found in the Oligocene of Victoria and the Upper Eocene, Miocene and Pliocene of New Zealand.

Occurrence.—Very rare.

Sub-fam. CASSIDULININAE.

Genus **Cassidulina** d'Orbigny.

CASSIDULINA CALABRA (Seguenza).

Burseolina calabra Seguenza, 1880, p. 138, pl. xiii., f. 7*a,b*.
Cassidulina calabra (Seg.), Brady, 1884, p. 431, pl. cxiii., f. 8*a-c*. Chapman, 1926, p. 42, pl. ix., f. 12.

Observations.—The original geological horizon for this species is Upper Miocene. I have since recorded it from the Upper Eocene and the Lower Miocene of New Zealand.

Occurrence.—Frequent.

CASSIDULINA SUBGLOBOSA Brady.

Cassidulina subglobosa Brady, 1884, p. 430, pl. liv., f. 17*a-c*. Chapman, 1907, p. 33, pl. iv., f. 84. Idem, 1926, p. 42, pl. ix., f. 14.

Observations.—The range of this species in fossil deposits commences in the Lower Cretaceous. It is a common form in the Victorian Oligocene and Miocene, and I have lately described it from the Upper Eocene and Lower Miocene of New Zealand.

Occurrence.—Very rare.

Fam. LAGENIDAE.

Sub-fam. LAGENINAE.

Genus **Lagena** Walker and Boys.

LAGENA HISPIDA Reuss.

Lagena hispida Reuss, 1863, p. 335, pl. vi., f. 77-79. Chapman, 1926, p. 45, pl. x., f. 1.

Observations.—Fossil specimens date from the Lias. It is found in the Oligocene of Victoria, and in the Upper Eocene and Upper Miocene of New Zealand. It is a fairly deep water form.

Occurrence.—Very rare.

Sub-fam. NODOSARIINAE.

Genus **Nodosaria** Lamarck.

Sub-genus **Dentalina** d'Orbigny.

NODOSARIA (D.) CONSOBRINA (d'Orbigny).

Dentalina consobrina d'Orbigny, 1846, p. 46, pl. ii., f. 1-3.
Nodosaria (*Dentalina*) *consobrina* (d'Orbigny), Brady, 1884, p. 501, pl. lxii., f. 23, 24. Chapman, 1926, p. 48, pl. i. f. 1-3; pl. iii., f. 27, 33, 34.

Observations.—Common throughout the Cretaceous and Tertiary, this species occurs in the Oligocene and Miocene of Victoria, and in the Upper Eocene and Miocene of New Zealand.

Occurrence.—Very rare.

Nodosaria (D.) obliqua (Linné).

Nautilus obliquus Linné, 1767, p. 1163.

Nodosaria (Dentalina) obliqua (L.), Brady, 1884, p. 513, pl. lxiv., f. 20-22. Chapman, 1917, p. 26, pl. iv., f. 39. Idem, 1926, p. 49, pl. iii., f. 23, 24, 37-39.

Observations.—This is quite a common species in the Oligocene and Miocene of Victoria. It has lately been recorded as of Upper Eocene and Lower Miocene ages in New Zealand.

Occurrence.—Very rare.

Nodosaria subtertenuata Schwager.

Nodosaria subtertenuata Schwager, 1866, p. 235, pl. vi., f. 74. Brady, 1884, p. 507, pl. lxii., f. 7, 8. Howchin, 1894, p. 364. Chapman, 1917, p. 27, pl. xii., f. 117.

Observations.—Schwager's original specimens came from the Pliocene of Kar-Nicobar. Subsequently it was obtained off Japan by the "Challenger" (Brady); and later it was discovered in Cretaceous beds in South and West Australia (Howchin and Chapman). It therefore appears to have originated in the Australian area and to have persisted here until Oligocene times.

Occurrence.—Very rare and small.

Nodosaria longiscata d'Orbigny.

Nodosaria longiscata d'Orbigny, 1846, p. 32, pl. i., f. 10-12. Sherborn and Chapman, 1889, p. 486, pl. xi., f. 17, 18. Chapman, 1926, p. 51, pl. xi., f. 7.

Observations.—This is a Tertiary species, dating from the Eocene. It has lately been found in the Upper Eocene of New Zealand.

Occurrence.—Rare; typical.

Genus **Frondicularia** Defrance.

Frondicularia cf. decheni Reuss.

Frondicularia decheni Reuss, 1860, p. 191, pl. iv. f. 3. Perner, 1897, p. 67, pl. iii., f. 3; pl. v., f. 6, 15. Chapman, 1917, p. 30, pl. vi., f. 53.

Observations.—The present example is of somewhat irregular growth, but it agrees in the almost parallel edges and the striate surface. This species has hitherto been known as a Cretaceous fossil, both in Europe and Australia. Here it therefore persists to the Oligocene.

Occurrence.—Very rare.

Genus **Trifarina** Cushman.

Trifarina bradyi Cushman.

Rhabdogonium tricarinatum Brady (*non* d'Orbigny), 1884, p. 525, pl. lxvii., f. 1-3.

Triplasia tricarinatum (d'Orbigny). Cushman, 1913, p. 62, pl. xxxix., f. 2.

Rhabdogonium tricarinatum (d'Orbigny). Heron-Allen and Earland, 1923, p. 158.

Trifarina bradyi Cushman, 1923, p. 99, pl. xxii., f. 3-9.

Observations.—It has been pointed out by Cushman that the recent species resembling *Rhabdogonium* of the Cretaceous, in general aspect, are distinct from d'Orbigny's generic type in having affinities with *Uvigerina*. The present Oligocene occurrence compares with the recent rather than the Cretaceous form, and it has also been met with in the Oligocene of Port Phillip, Victoria.

Occurrence.—Rare; typical.

Genus **Marginulina** d'Orbigny.

Marginulina bullata Reuss.

Marginulina bullata Reuss, 1845-6, p. 29, pl. xiii., f. 34-38. Chapman, 1926, p. 56, pl. iii., f. 48.

Observations.—This form is an inflated modification of *M. glabra*. It is common in the Cretaceous and Lower Tertiaries, and has occurred in the Upper Eocene, in New Zealand.

Occurrence.—Very rare.

Marginulina costata (Batsch).

Nautilus costatus Batsch, 1791, pl. i., f. 1*a-g*.

Marginulina costata (Batsch). Brady, 1884, p. 528, pl. lxv., f. 10-13. Sherborn and Chapman, 1889, p. 487, pl. xi., f. 28. Chapman, 1917, p. 26, pl. vii., f. 63, 64. Idem, 1926, p. 56, pl. iii., f. 49, 51, 54.

Observations.—This species occurs in all formations from the Lias upwards. It has been found in the Cretaceous of Gingin, W.A.; in the Oligocene of Port Phillip, Victoria; and in the Upper Eocene of New Zealand.

Occurrence.—Very rare.

Marginulina glabra d'Orbigny.

Marginulina glabra, d'Orbigny, 1826, p. 259, No. 6; Modèles, No. 55. Brady, 1884, p. 527, pl. lxv., f. 5, 6. Chapman, 1917, p. 33, pl. vii., f. 65. Cushman, 1923, p. 127, pl. xxxvi., f. 5, 6. Chapman, 1926, p. 57, pl. iii., f. 46*a,b*, 47*a,b*.

Observations.—The present example is a large and stout form. It is comparable with specimens found in the Oligocene and Miocene of Victoria. In New Zealand it occurs fossil in the Upper Eocene. It was also recorded from the chalk of Gingin, W.A.

Occurrence.—Very rare.

Genus **Vaginulina** d'Orbigny.

Vaginulina legumen (Linné).

Nautilus legumen Linné, 1767, p. 1164, No. 288.
Vaginulina legumen (L.), Chapman, 1917, p. 33, pl. viii., f. 67. Idem, 1926, p. 58, pl. i., f. 2.

Observations.—The vaginuline forms of this roundly depressed smooth type are common in Mesozoic and Lower Tertiary strata, and found more rarely in later deposits. It occurs with more frequency in the Oligocene and Miocene of Victoria, and in the Upper Eocene of New Zealand; also in the Cretaceous of Gingin.

Occurrence.—Common.

Genus **Cristellaria** Lamarck.

Cristellaria bronni (Römer).

Planularia bronni (Römer), Reuss, 1862, p. 70, pl. vii., f. 13*a,b*. Chapman, 1894, p. 649, pl. ix., f. 12*a,b*, 13*a,b*. Idem, 1917, p. 36, pl. viii., f. 77.

Observations.—This species is another of the hitherto Cretaceous types which has persisted into Oligocene times. It is closely comparable to the Gingin examples.

Occurrence.—Very rare.

Cristellaria wetherellii (Jones).

Marginulina sp., Sowerby, 1834, p. 134, pl. ix., f. 12.
Marginulina wetherellii Jones, 1854, p. 37. Parker and Jones, 1859, p. 350.
Marginulina fragraria Gümbel, 1870 (1868), p. 635, pl. i., f. 58*a-c*.
Cristellaria wetherellii (Jones), Chapman, 1926, p. 66, pl. iv., f. 4*a,b*, 5*a,b*.

Observations.—*C. wetherellii* is a well-known species in the Lower Eocene (London Clay) in the Oligocene of Hungary, and the Middle Eocene of Bavaria. In New Zealand it is found in the Upper Eocene. In recent soundings it has been dredged at 155 and 350 fathoms.

Occurrence.—Common.

Cristellaria aculeata d'Orbigny.

Cristellaria aculeata d'Orbigny, 1826, p. 292, No. 14. Brady, 1884, p. 555, pl. lxxxi., f. 4, 5. Chapman, 1926, p. 58, pl. xii., f. 6.

Observations.—The present form is of the similar tuberculate variety found in the Upper Eocene of New Zealand. It was originally recorded from the Pliocene of Siena, and is a living species in West Indian Seas.

Occurrence.—Very rare.

CRISTELLARIA GIBBA d'Orbigny.

Cristellaria gibba d'Orbigny, 1826, p. 292, pl. xxiii., f. 14*a,b.* Chapman, 1917, p. 37, pl. ix., f. 82. Idem, 1926, p. 61, pl. iv., f. 14*a,b.*

Observations.—The history of this species commences in the Lower Cretaceous (Aptian) of Surrey, England; it occurs at the base of the Upper Cretaceous (Hils) in Germany; and in the Gingin Chalk of W. Australia. In New Zealand *C. gibba* is a fairly common form in the Upper Eocene. Its range extends through the Tertiary, and it is a living form in shallow to moderately deep water.

Occurrence.—Very rare.

CRISTELLARIA OVALIS Reuss.

Cristellaria ovalis Reuss, 1845-6, p. 34, pl. viii., f. 9*a,b;* pl. xii., f. 19*a,b;* pl. xiii., f. 60*a*-63*b*. Howchin, 1907, p. 42. Chapman, 1917, p. 35, pl. viii., f. 75.

Observations.—This is one of the *C. gibba* type, but having a more depressed shell. It has hitherto been regarded as a Gault and Cenomanian fossil, but was also found in the Chalk of Gingin.

Occurrence.—Very rare.

CRISTELLARIA ORBICULARIS (d'Orbigny).

Robulina orbicularis d'Orbigny, 1826, p. 288, pl. xv., f. 8, 9.
Cristellaria orbicularis (d'Orb.), Brady, 1884, p. 549, pl. lxix., f. 17. Howchin, 1907, p. 42. Chapman, 1926, p. 63, pl. iv., f. 20*a,b.*

Observations.—Professor Howchin found this species in the Chalk of Gingin, W.A. It occurs throughout the Cainozoic series, and is also an Upper Eocene form in New Zealand.

Occurrence.—Very rare.

CRISTELLARIA CULTRATA (Montfort).

Robulus cultratus Montfort, 1808, p. 215, 54^{me} genre.
Cristellaria cultrata (Montf.), Brady, 1884, p. 550, pl. lxx., f. 4-8. Chapman, 1926, p. 61, pl. i., f. 6; pl. iv., f. 9*a,b,* 15*a,b,* 27*a,b,* 30*a,b,* 31.

Observations.—This species is found in almost all fossil deposits, from the Lias to the present day. It is found in shallow to moderately deep water. The Australian occurrences are in the Cretaceous (Gingin), and in Oligocene beds (Port Phillip). In New Zealand *C. cultrata* was found in the Upper Cretaceous, Upper Eocene and Miocene.

Occurrence.—Common.

Genus **Flabellina** d'Orbigny.

FLABELLINA RUGOSA d'Orbigny.

Flabellina rugosa d'Orbigny, 1840, p. 23, pl. ii., f. 4, 5, 7. Reuss, 1845-6, p. 33, pl. viii., f. 31-34; pl. xiii., f. 49, 53. Perner, 1897, p. 72, pl. v., f. 10, 16, 17, 19. Chapman, 1917, p. 39, pl. x., f. 90.

Observations.—This is a most interesting survivor of the Cretaceous fauna. It was met with in the Cretaceous of Gingin, where it is moderately common.

Occurrence.—Very rare.

Sub-fam. POLYMORPHININAE.

Genus **Polymorphina** d'Orbigny.

POLYMORPHINA COMMUNIS d'Orbigny.

Polymorphina (*Guttulina*) *communis* d'Orbigny, 1826, p. 266, pl. xii., f. 1-4; Modèle, No. 62.

Polymorphina communis d'Orbigny. Brady, 1884, p. 568, pl. lxxii. f. 19. Chapman, 1917, p. 41, pl. x., f. 95. Idem, 1926, p. 67, pl. v., f. *7a,b*.

Observations.—This species has an extended geological range. In Australia it occurs in both Oligocene and Miocene, as well as in the Cretaceous. In New Zealand it has been noted from the Eocene and Miocene.

Occurrence.—Frequent.

POLYMORPHINA OBLONGA d'Orbigny.

Polymorphina oblonga d'Orbigny, 1846, p. 232, pl. xii., f. 29-31. Cushman, 1913, p. 88, pl. xxxvii., f. 6. Chapman, 1926, p. 68, pl. xiv., f. 2.

Observations.—This form is quite a common one in the Oligocene and Miocene of Victoria. It has also occurred in the Oligocene of Kakanui, New Zealand.

Occurrence.—Frequent.

Genus **Siphogenerina** Schlumberger.

SIPHOGENERINA COLUMELLARIS (Brady).

Sagrina columellaris Brady, 1884, p. 591, pl. lxxv., f. 15-17.

Siphogenerina columellaris (Brady), Egger, 1893, p. 316, pl. ix., f. 28, 31, 33. Cushman, 1913, p. 104, pl. xlvii., f. 2, 3.

Observations.—The occurrence here of this species places it much further back in the geological record than hitherto, since it has not before been found in the Australian Tertiaries.

Occurrence.—Very rare.

SIPHOGENERINA BIFRONS (Brady).

Sagrina bifrons Brady, 1884, p. 582, pl. lxxv., f. 18-20.
Siphogenerina (*Sagrina*) *bifrons* (Brady), Egger, 1893, p. 317, pl. ix., f. 25, 26, 29.
Siphogenerina bifrons (Brady), Cushman, 1913, p. 105, pl. xlv., f. 1, 2, 5-7.

Observations.—This seems to be the first fossil occurrence of the above species. It is well distributed in the Pacific and along the Australian Coast. The present examples are megalospheric.

Occurrence.—Rare.

Fam. GLOBIGERINIDAE.

Genus **Globigerina** d'Orbigny.

GLOBIGERINA BULLOIDES d'Orb.

Globigerina bulloides d'Orbigny, 1826, p. 277, No. 1, Modèles, Nos. 17, 76. Cushman, 1914, p. 5, pl. ii., f. 7-9, pl. ix. Chapman, 1917, p. 43, pl. xii., f. 1-3. Idem, 1926, p. 72, pl. v., f. 35*a-d*.

Observations.—The examples found here are well-developed. *G. bulloides* is common in many Australian Tertiary deposits.

Occurrence.—Rare.

Genus **Sphaeroidina** d'Orbigny.

SPHAEROIDINA BULLOIDES d'Orbigny.

Sphaeroidina bulloides d'Orbigny, 1826, p. 267, No. 1, Modèles, No. 65. Cushman, 1914, p. 18, pl. x., f. 7; pl. xii., f. 1. Chapman, 1917, p. 45, pl. xii., f. 127. Idem, 1926, p. 74, pl. xv., f. 2.

Observations.—This species is also of common occurrence in Cretaceous and Tertiary deposits, both in Australia and New Zealand.

Occurrence.—Frequent.

Genus **Pullenia** Parker and Jones.

PULLENIA QUINQUELOBA (Reuss).

Nonionina quinqueloba Reuss, 1851, p. 47, pl. v., f. 31*a,b*.
Pullenia quinqueloba (Reuss), Brady, 1884, p. 617, pl. lxxxiv., f. 14, 15.

Observations.—The related *P. sphaeroides* is the commoner form of the genus in Australian fossil deposits, but I have also recorded *P. quinqueloba* from the borings in the Mallee.

Occurrence.—Very rare.

Fam. ROTALIIDAE.

Sub-fam. ROTALIINAE.

Genus **Discorbina** Parker and Jones.

DISCORBINA GLOBULARIS (d'Orbigny).

Rosalina globularis d'Orbigny, 1826, p. 271, pl. xiii., f. 1-4; Modèle, No. 69.
Discorbina globularis (d'Orb.), Brady, 1884, p. 643, pl. lxxxvi., f. 8, 13.

Observations.—*D. globularis* is a well-known Tertiary fossil, and in recent soundings usually affects shallow waters.

Occurrence.—Very rare.

DISCORBINA ARAUCANA (d'Orbigny).

Rosalina araucana d'Orbigny, 1839, p. 44, pl. vi., f. 16-18.
Discorbina araucana (d'Orb.), Brady, 1884, p. 645, pl. lxxxvi., f. 10, 11.

Observations.—As a living species this form is well known in southern waters. It has been found in Tertiary beds in the Mallee Bores.

Occurrence.—Very rare.

DISCORBINA VILARDEBOANA (d'Orbigny).

Rosalina vilardeboana d'Orbigny, 1839, p. 44, pl. vi., f. 13-15.
Discorbina vilardeboana (d'Orb), Brady, 1884, p. 645, pl. lxxxvi., f. 9, 12; pl. lxxxviii. f. 2. Howchin, 1889, p. 12. Chapman, 1926, p. 77, pl. xv., f. 10.

Observations.—This species dates from Cretaceous times (Aptian of England), and is also known from the Oligocene of W. Victoria and from the Upper Eocene of New Zealand.

Occurrence.—Very rare.

Genus **Planorbulina** d'Orbigny.

PLANORBULINA LARVATA P. and J.
var. INAEQUILATERALIS Heron-Allen and Earland

Planorbulina larvata P. and J., var. *inaequilateralis,* Heron-Allen and Earland, 1924, p. 174, pl. xii., f. 85-90.

Observations.—This interesting variety of *P. larvata* was discovered by Heron-Allen and Earland in the marls of the Filter quarries at Batesford, Victoria, which deposit is of Miocene (Burdigalian age), and therefore later than the present one from Exmouth Gulf.

Occurrence.—Very rare.

Genus **Truncatulina** d'Orbigny.

Truncatulina lobatula (W. and J.).

Nautilus lobatulus Walker and Jacob, 1798, p. 642, pl. xiv., f. 36.
Truncatulina lobatula (W. and J.), Brady, 1884, p. 660, pl. xcii., f. 10; pl. xciii., p. 78, pl. xv., f. 12.

Observations.—One of the most abundant rotalines in Australian Tertiary and Recent deposits. The present examples are typical.

Occurrence.—Common.

Truncatulina refulgens (Montfort).

Cibicides refulgens Montfort, 1808-10, p. 122, 31me genre.
Truncatulina refulgens (Montfort), Brady, 1884, p. 659, pl. xcii., f. 7-9. Chapman, 1926, p. 78, pl. xv., f. 13.

Observations.—This is a common fossil in the Australian and New Zealand Tertiary deposits.

Occurrence.—Rare; typical.

Truncatulina mundula Brady, Parker and Jones.

Truncatulina mundula Brady, Parker and Jones, 1888, p. 228, pl. xlv., f. 25.
Planorbulina mundula B., P. and J., Goës, 1896, p. 71.
Truncatulina mundula, B., P. and J., Cushman, 1915, p. 41, pl. xiii., f. 4 (text-fig. 45*a-c*).

Observations.—*T. mundula* is a common species in Australian Tertiary marls, and is well represented living in Pacific faunas. The specimens here met with are perhaps rather more sharply keeled than usual.

Occurrence.—Frequent.

Truncatulina wuellerstorfi (Schwager).

Anomalina wuellerstorfi Schwager, 1866, p. 258, pl. vii., f. 105, 107.
Truncatulina wuellerstorfi (Schw.), Brady, 1884, p. 662, pl. xciii., f. 8, 9. Chapman, 1917, p. 46, pl. xi., f. 106. Idem, 1926, p. 79, pl. xvi., f. 3.

Observations.—This species was found in the Gingin Chalk of W. Australia, and it is also a common fossil in the Tertiaries. In New Zealand it was found in the Upper Eocene and Miocene.

Occurrence.—Frequent.

Genus **Siphonina** Reuss.

Siphonina reticulata (Czjzek).

Rotalina reticulata Czjzek, 1848, p. 145, pl. xiii., f. 7-9.
Truncatulina reticulata (Cz.), Brady, 1884, p. 669, pl. xcvi., f. 5-8.

Siphonina reticulata (Cz.), Cushman, 1921, p. 322, pl. lxx., f. 3*a-c*.

Observations.—This is one of the regular components of the microzoic fauna of the Australian Tertiaries, and ranges from the Oligocene upwards. The present examples are well developed.

Occurrence.—Rare.

Genus **Anomalina** Parker and Jones.

Anomalina ammonoides (Reuss).

Rosalina ammonoides Reuss, 1845-6, p. 36, pl. viii., f. 53; pl. xiii., f. 66.

Anomalina ammonoides (Rss.), Brady, 1884, p. 672, pl. xciv., f. 2, 3. Chapman, 1926, p. 79, pl. v., f. 31*a-c*, 34*a-c*.

Observations.—One of the most abundant of the Tertiary Foraminifera in Australia, this species is here represented by well grown examples.

Occurrence.—Frequent.

Anomalina grosserugosa (Gümbel).

Truncatulina grosserugosa Gümbel, 1870, p. 660, pl. ii., f. 104.

Anomalina grosserugosa (Gümbel), Cushman, 1915, p. 45, pl. xx., f. 1. Chapman, 1926, p. 80, pl. xvi., f. 5.

Observations.—This fairly deep water form is a common species in the Tertiary deposits of Australia and New Zealand.

Occurrence.—Common. Rather small.

Genus **Carpenteria** Gray.

Carpenteria proteiformis Goës.

Carpenteria balaniformis Gray, var. *proteiformis* Goës, 1882, p. 94, pl. vi., f. 208-14; pl. vii., f. 215-219.

Carpenteria proteiformis Goës, Brady, 1884, p. 679, pl. xcvii., f. 8-14. Chapman, 1926, p. 81, pl. xvi., f. 7.

Observations.—This is a common Oligocene species in Australia and New Zealand. It also occurs in the Miocene of the Victorian Mallee Bores and Batesford.

Occurrence.—Rare.

Genus **Rotalia** Lamarck.

?Rotalia calcar (d'Orbigny).

Calcarina calcar d'Orbigny, 1826, p. 276, No. 1, Modèle, No. 34.

Rotalia calcar (d'Orbigny), Brady, 1884, p. 709, pl. cviii., f. 3, ?4.

Observations.—There is a worn test of a foraminifer in these washings, which is referred, provisionally, to this species. *R. calcar* is a well known form in the Australian Tertiary limestones.

Occurrence.—Very rare.

Genus **Calcarina** d'Orbigny.

CALCARINA DEFRANCII d'Orbigny.

Calcarina defrancii d'Orbigny, 1826, p. 276, No. 3, pl. xiii., f. 5-7.
Rotalia calcar Chapman, 1909, (*non* d'Orb.), p. 289, pl. iii., f. 2.
Calcarina defrancii d'Orb., Heron-Allen and Earland, 1924, p. 182.

Observations.—This is a common species in the Miocene of Batesford, Victoria. Although there accompanied by *Rotalia calcar,* my figures were erroneously referred to the latter species, as pointed out by Heron-Allen and Earland.

Occurrence.—Rare. Rather worn examples.

Genus **Baculogypsina** Sacco.

BACULOGYPSINA SPHAERULATA (Parker and Jones).

Orbitolina sphaerulata Parker and Jones, 1860, p. 33, No. 8.
Tinoporus baculatus Carpenter (*non* Montfort), 1861, p. 577, pls. xviii., xxi.
Baculogypsina sphaerulatus (P. and J.), Cushman, 1919, pl. xliv., f. 6. Idem, 1921, p. 359, pl. lxxv., f. 6.

Observations.—This is an abundant species in all warm waters of Australia and the Pacific. It is extremely interesting to find it fossil and so far down in the Tertiary series.

Occurrence.—Very rare; small, but otherwise typical.

Genus **Gypsina** Carter.

GYPSINA GLOBULUS (Reuss).

Ceriopora globulus Reuss, 1847, p. 33, pl. v., f. 7.
Gypsina globulus (Reuss), Heron-Allen and Earland, 1924, p. 183, pl. xiv., f. 117, 118.

Observations.—*G. globulus* is quite an abundant form in Australian Tertiary deposits, and as a recent form it affects coral zones.

Occurrence.—Rare; typical.

Fam. NUMMULITIDAE

Sub-fam. POLYSTOMELLINAE.

Genus **Polystomella** Lamarck.

POLYSTOMELLA CRATICULATA (Fichtel and Moll).

Nautilus craticulatus Fichtel and Moll, 1798, p. 51, pl. v., f. *h-k.*
Polystomella craticulata (F. and M.), Brady, 1884, p. 739, pl. cx., f. 16, 17. Howchin, 1889, p. 16.

Observations.—This is also a coral reef species. It occurs in the Oligocene and Lower Pliocene of Muddy Creek, and in the basal Miocene of the Mallee Bores, both in Victoria.

Occurrence.—Very rare.

Sub-fam. NUMMULITINAE.

Genus **Amphistegina** d'Orbigny.

Amphistegina lessonii d'Orbigny.

Amphistegina lessonii d'Orbigny, 1826, p. 304, No. 3, pl. xvii., f. 1-4; Modèle, No. 98. Chapman, 1926, p. 90, pl. i., f. 19.

Observations.—*A. lessonii* is a universally distributed and abundant form in the Australian and New Zealand Tertiaries.

Occurrence.—Very rare.

Genus **Operculina** d'Orbigny.

Operculina complanata (Defrance).

Lenticulites complanata Defrance, 1822, p. 453.

Operculina complanata (Defr.), Brady, 1884, p. 743, pl. cxiii., f. 3-5, 8. Chapman, 1926, p. 91, pl. xviii., f. 1; pl. xix., f. 3.

Observations.—This is a common Tertiary foraminifer. Several fragments of this form were found in the washings from the Cape Range limestone.

Occurrence.—Frequent.

Genus **Heterostegina** d'Orbigny.

Heterostegina depressa d'Orbigny.

Heterostegina depressa d'Orbigny, 1826, p. 305, No. 2, pl. xvii., f. 5-7; Modèle No. 99. Chapman, 1910, p. 295. Idem, 1926, p. 92, pl. xviii., f. 2.

Observations.—This is one of the fairly common forms in the Miocene of Australia and New Zealand.

Occurrence.—Frequent.

Sub-fam. CYCLOCLYPEINAE.

Genus **Cycloclypeus** Carpenter.

Cycloclypeus pustulosus Chapman.

(Plate XII., Figs. 1, 3.)

Cycloclypeus pustulosus Chapman, 1905, p. 271, pl. v., f. 1; pl. vi., f. 2; pl. vii., f. 2. Idem, 1909, p. 295, pl. lii., f. 6; pl. lv., f. 4. Id., 1926, p. 92, pl. xviii., f. 3*a,b*.

Observations.—This species appears to have a somewhat extended range, from Oligocene to Miocene. The present examples are very large, sometimes measuring as much as 20 mm. in diam-

eter. The holotype, from the New Hebrides, measures only 6 mm. in diameter. Both are probably microspheric.

Occurrence.—Common.

Genus **Lepidocyclina** Gümbel.

Sub-genus **Eulepidina** H. Douvillé.

LEPIDOCYCLINA (EULEPIDINA) DILATATA (Michelotti).

(Plate XII., Figs. 1, 2.)

Orbitoides dilatata Michelotti, 1861, p. 17, pl. i., f. 1, 2.
Orbitoides (*Lepidocyclina*) *dilatata* Mich., Gümbel, 1870, p. 681, pl. iv., f. 45*a,b*, 46, 47.
Lepidocyclina dilatata (Mich), A. Silvestri, 1910, p. 139, pl. xxv., f. 9*a-c;* pl. i., f. 4-10. Chapman, 1926, p. 93, pl. xviii., f. 4*a,b;* pl. xx., f. 1.

Observations.—The present examples average about 12 mm. in diameter, and are thus more than twice as large as the New Zealand specimens from North Auckland and Titirangi.

The distribution of *L. dilatata* in East Borneo, as recently given by Van der Vlerk (1925, Table), shows this species to be there characteristic of the Oligocene (that is, " Post-Eocene Naintoepo Beds ") above which succeed the *Lepidocyclina tournoueri* beds (the " Poeloe-Balang Beds ").

Occurrence.—Frequent.

Genus **Miogypsina** Sacco.

MIOGYPSINA cf. IRREGULARIS (Michelotti).

Nummulites irregularis Michelotti, 1841, p. 296, pl. iii., f. 5.
Miogypsina irregularis (Mich)., Schlumberger, 1900, p. 328, pl. ii., f. 1-7, 9, 10; pl. iii., f. 17. Chapman, 1926, p. 93, pl. xviii., f. 5*a,b;* pl. xx., f. 3, 4.

Observations.—Fragmentary specimens of this or an allied form occur in the washings. It may belong to an earlier type of foraminifera, or if referable to the above, shows, as in New Zealand, a commingling of Oligocene and Miocene forms.

Occurrence.—Frequent.

Phylum **MOLLUSCOIDEA.**

Class POLYZOA.

Order CYCLOSTOMATA.

Fam. CRISIIDAE.

Genus **Crisia** Lamouroux.

CRISIA GRACILIS MacGillivray.

Crisia gracilis MacGillivray, 1895, p. 118, pl. xvi., f. 5.

Observations.—The original and only locality for this species is

the Oligocene beds at Clifton Bank, Muddy Creek, Western Victoria.

Occurrence.—Very rare.

Phylum **MOLLUSCA.**

Class PELECYPODA.

Fam. DIMYIDAE.

Genus **Dimya** Roualt.

DIMYA DISSIMILIS Tate.

Dimya dissimilis Tate, 1886, p. 100, pl. iii., f. 9*a-c*. Harris, 1897, p. 306.

Observations.—A right valve of a subcircular form, with fine radial and undulate concentric ornament, occurs here. The inside of the valve is quite smooth, and thus precludes it from a comparison with *D. sigillata* Tate. This species has an extensive geological range within south-eastern Australia, from the Oligocene to Lower Pliocene.

Occurrence.—One valve.

Phylum **ARTHROPODA.**

Super Order OSTRACODA.

Fam. CYPRIDAE.

Genus **Aglaia** G. S. Brady.

AGLAIA CLAVATA G. S. Brady.

Aglaia clavata G. S. Brady, 1880, p. 34, pl. vi., f. 4*a-d*.

Observations.—This is the first time that *A. clavata* has occurred fossil. It only shows, in common with many other Australian recent species of ostracoda, that the living fauna was established in southern waters in early Tertiary times.

Occurrence.—Very rare.

Fam. CYTHERIDAE.

Genus **Cythere** O. F. Müller.

CYTHERE LACTEA G. S. Brady.

Cythere lactea G. S. Brady, 1865, p. 377, pl. lx., f. 3*a-c*. Idem, 1880, p. 91, pl. xxii., f. 1*a-d*. Chapman, 1914, p. 36, pl. vii., f. 15.

Observations.—The present examples are small but typical valves belonging to the above species. *C. lactea* occurred in the Janjukian (Miocene) of the Mallee Bores, and it persists to the present day round the Australian coast.

Occurrence.—Two opposite valves.

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EXPLANATION OF PLATES.

Fig. 1.—Photograph of naturally fractured limestone from Exmouth Gulf, showing abundance of tests of *Cycloclypeus* and *Lepidocyclina*. Slightly reduced.

Fig. 2.—Horizontal section through test of *Lepidocyclina dilatata* (Michelotti); showing primordial and circumambient chamber in median section. The inner chamber has a diameter of 42 micra, the outer 77 μ. ×28.

Fig. 3.—Section of the limestone, with a portion of the test of *Cycloclypeus pustulosus* Chapm., seen in median aspect. The chamberlets measure 27 by 13μ. ×28.

Fig. 4.—*Bolivina spiroplectiformis*, sp. nov. Test. × 104.